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DMAHTC'S SUPPORT TO NATIONAL OCEAN SURVEY LORAN C CHARTING,(U)
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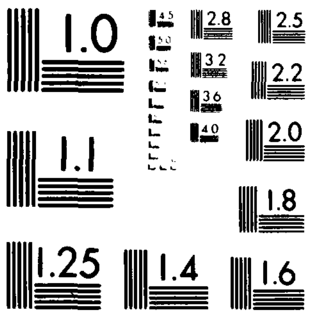

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The selection of LORAN-C as the primary Radionavigation System for the U.S. Coastal Confluence Zone requires by, joint agreement, that DMAHTC, USCG, and NOS provide corrections to LORAN-C Lattices overprinted on NOS Charts. This paper reviews the techniques used to compute these corrections. It also gives the status of the LORAN-C System.

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DMAHTC's SUPPORT TO NATIONAL OCEAN SURVEY LORAN-C CHARTING

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ABSTRACT

The selection of Loran-C as the primary radionavigation system for the United States Coastal Confluence Zone (CCZ) requires, by joint agreement, that the Defense Mapping Agency Hydrographic/Topographic Center provide corrections to Loran-C lattices overprinted on National Ocean Survey (NOS) charts. Additional Secondary Factor (ASF) Corrections to warp the lattices are necessary if the system is to meet ¼-nautical mile or better positioning accuracy required by the Department of Transportation (DOT) and specified in the 1977 National Plan for Navigation.

The Coast Guard, which has statutory responsibility for the Loran-C Navigation System, expects it to be the principal aid to navigation for civil use in the CCZ until the year 2000. For Department of Defense (DoD) purposes the system will be replaced eventually by the NAVSTAR Global Positioning System (GPS).

This paper reviews future plans for refinement of the techniques to compute ASF corrections, as well as past and present computational methods. In addition, it examines the status of the Loran-C Navigation System and the status of NOS charts which support the system.

The U.S. Coast Guard has surveyed critical areas in the CCZ to verify the accuracy of Loran-C NOS chart lattices. An example survey in the offshore area of the west coast is depicted and discussed.

TABLE OF CONTENTS

DMAHTC's SUPPORT TO NATIONAL OCEAN SURVEY LORAN-C CHARTING

Introduction

On May 16, 1974, the Secretary of Transportation, with the advice of the U.S. Coast Guard, publicly announced the selection of Loran-C as the government-provided radionavigation system for the U.S. Coastal Confluence Zone (CCZ) and the Great Lakes. An annex, to this effect, was published in the Department of Transportation (DOT) National Plan for Navigation and was published as a notice in the July 19, 1974, Federal Register.

The system will provide 95% assurance that a vessel can fix its position to a predicted accuracy of ¼ nautical mile (NM) within the Zone. This accuracy requirement is instituted so that a vessel will be navigated safely along a track to its destination or within a designated shipping lane. Existing lanes vary from 1 NM at the harbor entrances and in the Gulf of Mexico Fairways to 5 NM at the outer limit of the CCZ. The CCZ is defined as:

> "the seaward approaches to land, the inner boundary of which is the harbor entrance and the outer boundary of which is 50 nautical miles offshore or the edge of the Continental shelf (100 fathom curve) whichever is greater."

The accuracy requirement affects the cartographer as well as the mariner. Therefore, the National Ocean Survey (NOS), which publishes

charts for the CCZ, engages in a program with the U.S. Coast Guard (USCG) and the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) to provide the coastal navigator with charts overprinted with lattices which meet ¼-NM accuracy requirement.

The accuracy of the lattice depends upon knowledge of the exact signal transit time between the Loran-C transmitting antenna and the receiving antenna. To achieve this accuracy the lattice is adjusted to compensate for the phase retardation of the signal as it passes over an all seawater path as compared to free space; and to compensate for an additional phase retardation when the signal passes over land paths or partial seawater-land paths. These errors are known as the Secondary Factor (SF) and the Additional Secondary Factor (ASF) respectively.

This paper presents an overview of the Loran-C Radionavigation System, the charts which support the system; and the methods used to derive ASF corrections which are used to warp the chart lattices which would otherwise be in error by the magnitude of the ASF.

JOINT AGREEMENT

At present, with respect to Mapping, Charting, and Geodesy (MC&G) products, a quasi-official agreement, consisting of correspondence and memoranda, exists between the USCG, DMA, and NOS. An official agreement which outlines the roles and responsibilities of the respective agencies is being published. Excerpts from this agreement defining Agency tasks are outlined below.

The USCG, as operator of the Loran-C radionavigation system, will coordinate all civil, and with the advice of the Department of Defense, military MC&G production relating to the system. It will conduct surveys to insure that Loran-C coverage exists with respect to envelope-to-cycle difference (ECD) and signal-to-noise ratio (SNR). To allow for timely production of coastal charts, the USCG will be responsible for the verification of ¼-NM accuracy, (95% confidence or 2dRMS), for all coastal Loran-C service. In conjunction with NOS, it will assist in surveys of coastal waters of the United States to allow production of Loran-C charts meeting the MC&G standards set forth above. USCG will provide funds to NOS for surveying systems and Loran-C receivers needed for their participation in the MC&G activity.

DMA, for Loran-C civil needs, will prepare grid predictions from its data base. Based on analysis and verification of the predicted grid from a USCG and/or NOS survey, it will produce revisions to the initial grid predictions. DMA will print charts with the revised data for the NOS geographical areas of charting responsibility, and will provide the data directly to NOS (with a copy to USCG) for charting Loran-C lattices in the contiguous U.S. maritime regions. Further, DMA will act as a central collection point for all Loran-C information. DMA will use this information to update its data base and thus improve MC&G products in the future. Finally, DMA will prepare, distribute, and periodically update unclassified ASF tables for U.S. waters as specified in the Joint Chiefs of Staff (JCS) Master Plan for Navigation.

NOS will prepare and distribute Loran-C charts for U.S. coastal waters based on data received from DMA. In conjunction with the USCG, NOS will participate in Loran-C comparison surveys of U.S. coastal waters to enable production of Loran-C charts meeting MC&G standards. There will be no charge for use of NOS vessels on these missions. Further, whenever possible, NOS will provide equipment and operators for geodetic control of surveys accomplished either by NOS or the USCG, as well as necessary recovery and preparation of control points.

Suffice to say that, although the future tense is used in the preceding paragraphs, the actions are actually being carried out.

BASIC PRINCIPLES OF LORAN-C

Loran-C is a long range, hyperbolic, radionavigation system, employing time difference measurements of signals received by the navigator from at least three ground transmitting stations. One transmitter is designated the master and transmits a group of short pulsed signals of radio-frequency energy. Two or more secondary stations receive these signals and use them to synchronize their transmissions. At the proper respective times, each secondary station transmits a group of pulses similar to those transmitted by the master station. The signals are received aboard ship where the differences in times of arrival of the master signal and various secondary signals are measured and displayed on the indicator portion of the Loran-C set. The measured time difference (in microseconds) between receipt of the master signal and that of any one of the secondary signals represents a hyperbolic line of position. A Loran-C fix is obtained from two or more time difference readings. When plotted on a chart, the intersection of the

resultant hyperbolic lines defines a geographical position. Special Loran-C charts that display the hyperbolas are used for Loran-C navigation.

It has become possible in recent years to resolve a Loran-C fix without plotting on the special charts. This is accomplished by using digital computers specifically programed to convert the time difference readings to geographic coordinates. The time difference readings are entered in the computer either manually or automatically. The computed geographic coordinates are displayed by the receiver printed on paper, or stored on tape (i.e. magnetic or punched paper) for future analysis.

LORAN-C GENERAL SPECIFICATIONS AND PARAMETERS

The following parameters were used in the baseline length computation.

a. Signal propagation: Use the velocity of light in free space as 2.99792458 (10^8) meter/second and an index of refraction of 1.000338 at the surface for standard atmosphere.

b. Phase of the groundwave: As defined in the National Bureau of Standards (NBS) Circular 573.

c. Conductivity: Sigma = 5.0 mhos/meter (seawater). Baseline electrical distance computations were made assuming a smooth, all seawater transmisssion path between stations.

d. Permittivity of the Earth: e_2=80 (for seawater).

e. Altitude in meters h_2=0.

f. Parameter associated with the vertical lapse of the permittivity of the atmosphere: a = 0.75.

g. Frequency: 100 kHZ.

h. Spheroid: WGS 72 (equatorial radius: a = 6378135.0 meters, polar radius: b = 6356750.5 meters, flattening: f = (a-b/a = 1/298.26).

All operating Loran-C transmitting stations use a cesium beam frequency standard, the AN/FPN-54 Timer and the AN/FPN-60 Transmitter Control Set as basic timing and control equipment.

Predicted coverage: Derived from a combination of geometric limits and range limits. Where data are available, the predicted coverage may be modified to reflect real-world observations.

Clarinet Pilgrim: A communications system transmitted on Loran-C using pulse position modulation of pulses 3 through 8 of the pulse group. Modulation is balanced $\pm$ 1.0 microsecond.

TTY2: A communications system similar to Clarinet Pilgrim except pulses 1 and 2 are modulated.

Two Pulse Comms: A communications system similar to Clarinet Pilgrim except pulses 7 and 8 are modulated.

Geometric fix accuracy limit: Contour showing where a receiver, capable of furnishing time-difference (TD) readings with a standard deviation of 0.1μs, will provide a two line-of-position (LOP) fix accuracy of 1500 feet, 2 dRMS (95% confidence). This calculation considers the crossing angles of the two LOPs as well as the gradient (microsecond/nautical mile) of the hyperbolic grid.

Range limits: Determined from a combination of atmospheric noise, manmade noise, and signal strength. The predicted atmospheric noise

level is calculated for a typical point in the coverage area. The 95% noise levels for each 4 hour period of day for each of the 4 seasons as given in the World Distribution and Characteristics of Atmospheric Radio Noise documents of the Xth Plenary Assembly, Geneva, 1963 (CCIR Report 322) are used along with the methodology of calculation given in that report. Prime sources of atmospheric noise are electrical storms and other natural phenomena.

Noise: Manmade noise can be very significant in some areas and must be considered when determining the useful range of Loran-C. Sources of this type of noise are industrial equipment, radio transmissions, and, to a considerable extent, Loran-C signals from other chains. Due to other Loran-C signals, effective noise figures should be increased in areas where adjacent chains generate relatively strong interfering signals.

Signal to Noise Ratio: To determine the strength of the Loran-C signal, the power output of the transmitting station is used as a starting point. The predicted signal strength, coarsely corrected to reflect the conductivity of the path traveled, is combined with noise to determine the relative signal strength or signal-to-noise ratio (SNR). Where available, real-world observations may take precedence over calculated value of SNR. A SNR of one to three is used to define coverage.

LORAN SCHEDULES

On March 1980, original plans for expanded Loran-C service throughout the Coastal Confluence Zone and Great Lakes area as contained in

DOT's National Plan for Navigation (NPN) were completed. This expansion was accomplished by construction of 13 stations, which combined with 5 existing stations, formed 6 new Loran-C chains.

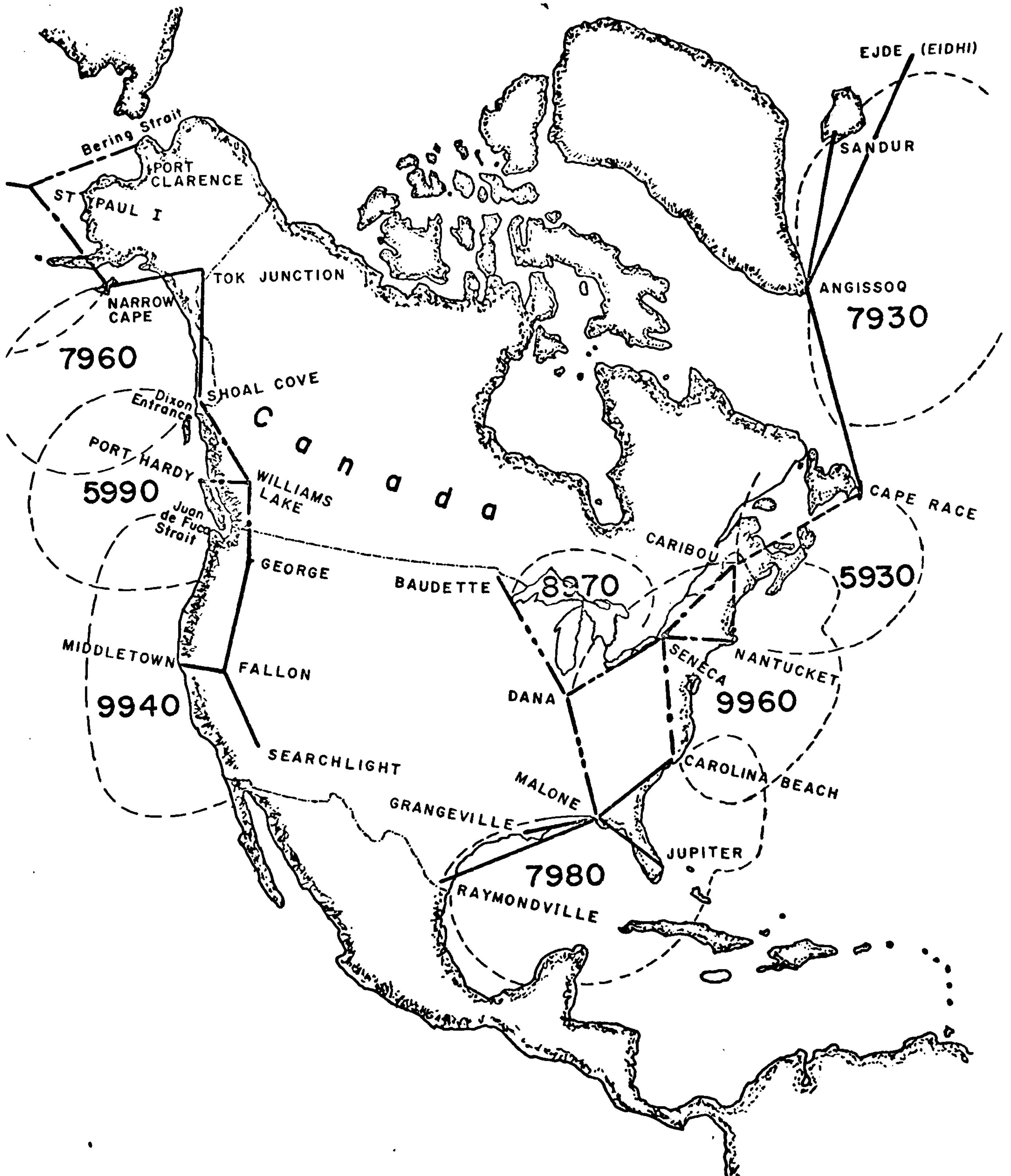
Loran-C service under the NPN was completed as listed below:

RATE	Chain	Action	Date Implemented
9940	West Coast	Operational	APR 77
7960	Gulf of Alaska	Operational	JUN 77
5990	Canadian West Coast	Operational	SEP 77
9960	Northeast	Operational	SEP 78
7980	Southeast (except Z)	Operational	DEC 78
9930	East Coast	Terminated	SEP 79
7980	Zulu	Operational	OCT 79
8970	Great Lakes	Operational	MAR 80

In addition, the Canadian East Coast Chain, Rate 5930, became operational on May 31, 1980.

As part of this Loran-C expansion the NPN calls for the phase-out of all U.S.-operated Loran-A stations. The Loran-A chains which have ceased operations or are scheduled for closure are as follows:

Overseas		Western Domestic	
Iwo Jima/Okinawa	31 DEC 77	Aleutian Islands	1 JUL 79
Mariana Islands	31 Dec 77	Gulf of Alaska	31 DEC 79
Marshall Islands	31 DEC 77	Hawaiian Islands	1 JUL 79
Estaca de Vares	31 DEC 77	U.S.West Coast	31 DEC 79



CHAIN COVERAGE UNITED STATES AND CANADA

Eastern Domestic	
West Indies	31 DEC 80
U.S. East Coast	31 DEC 80
Gulf of Mexico	31 DEC 80

CHART COVERAGE IN THE CCZ

At present, DMAHTC has provided NOS with approximately 400 charts. These charts include first editions and revised editions. As shown in figure 1, the U.S. portion of the CCZ is covered by ASF latticed charts for each rate depicted. The annually published NOS chart catalogs list NOS charts overprinted with ASF corrected lattices. Each chart contains one of the following notes:

> "The Loran-C lines of position overprinted on this chart have been prepared for use with groundwave signals and are presently compensated only for theoretical propagation delays, which have not yet been verified by observed data. Mariners are cautioned not to rely entirely on the lattices in inshore waters. Skywave corrections are not provided"

or

> "The Loran-C lines of position overprinted on this chart have been prepared for use with groundwave signals and are compensated with propagation delays computed from observed data. Mariners are cautioned not to rely entirely on the lattices in inshore waters. Skywave corrections are not provided."

BACKGROUND AND DESIGN OF THE LATTICE CORRECTIONS PROGRAMS

These programs are based on two fundamental concepts of radio theory: (1) radio waves travel outward from the transmitting antenna along radial paths and (2) these paths are great circles over the Earth's surface.

The low frequency, 90 to 110 kHz, of the Loran-C Radionavigation System is affected significantly by the electrical properties of the Earth. The effect is a decrease in velocity and an increase in propagation time. This phase retardation of radio wave is a function of ground conductivity. The values of phase retardation for a given ground conductivity are tabulated in the National Bureau of Standards (NBS) Circular 573; and they are the bases for computing theoretical ASF.

A great circle approximates a geodesic or straight line; therefore, its path can be defined by geodetic points. Points on the great circle may be used as control points to insure that the proper azimuth and distance are maintained regardless of chart projection and scale on which the great circle may be plotted. The technique to select any point and distance is incorporated in the ASF Correction Programs.

A great circle drawn on the appropriate chart or charts from the Loran-C station coordinates to the area under consideration spans various segments of land and water. Each segment will have a specific conductivity and distance. The total of these conductivity segments will determine the total phase retardation of the path. The actual measurement, done by either manual measurement or digitizing, provides the raw data for computation of ASF. After the raw data has been put in the proper format it is entered into a program which computes theoretical ASF by Millington's Method. It is based on the principal of reciprocity which states that in a linear, uniform propagation medium, the response of the medium to a source is unchanged when the source and the receiver are interchanged. The

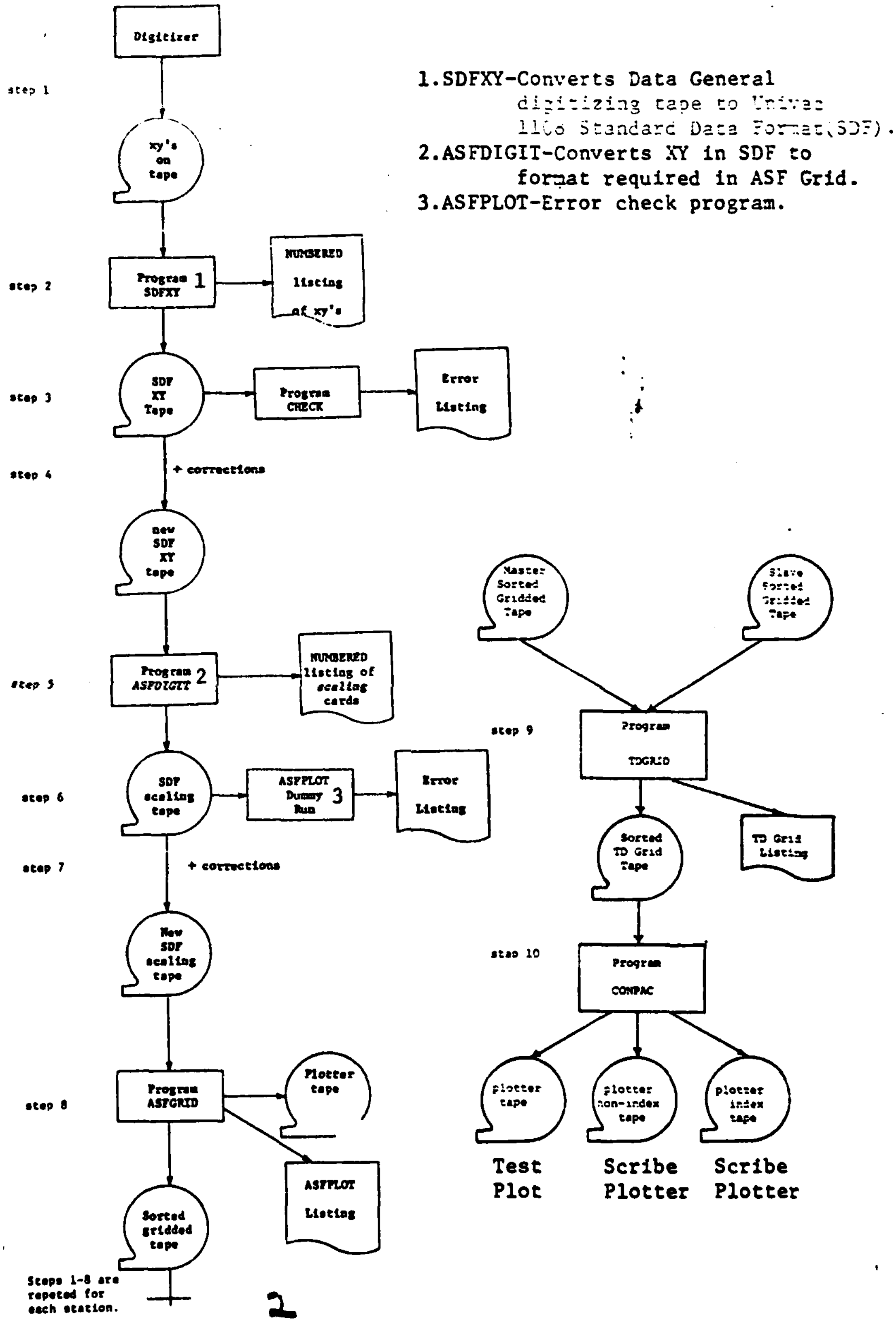


Fig. 2 Warped Lattice Flow Diagram

direction of a path from a source across a medium does not affect the response of the medium. This algorithm predicts a phase delay by computing a correction from source to transmitter and then a reciprocal correction. The values of the two corrections are averaged. The two values are not identical because the conductivity segments are biased, depending upon their proximity to the source. The amount of bias with respect to distance applied to the ground conductivity is set forth in NBS Circular 573 which is referred to above.

The WARPED LATTICE PROGRAM, developed in conjunction with the Naval Oceanographic Office, contours ASF corrected lattices on charts. Figure 2 depicts the production process. This program involves four basic stages:

- data preparation-inputs gridded data, interpreting for missing points.
- computation of contour grid line intersections
- generation of output for plotters
- chart to chart paging and edge matching.

To generate a hyperbolic lattice with the ASF correction included, this Program consists of three basic programs. They are:

- ASF Grid
- TD Grid
- Merge

The ASF GRID Program is a modification of the ASF Plot Program which DMAHTC currently uses to generate ASF correction values along azimuth lines radiating from the Loran-C transmitter. These values are used to

compute a grid of ASF corrections at 5' intervals of latitude and longitude. In preparing the input to this program the coverage area of the product chart must be broken down into smaller computational areas no larger than 8^{0} on a side. These areas are then gridded one by one in the program. After the last area is computed, the data is sorted to produce one large grid covering the entire product chart.

The TD GRID PROGRAM requires two input tapes (Master and Secondary) of gridded data, sorted according to increasing latitude and longitude. The area can be no larger than 4^{0} on a side for a 5' grid with overlap of 10' on each side to facilitate border matching. The program generates a gridded tape of TD values which have been corrected for ASF. This gridded tape is used for input to the MERGE Program.

The MERGE PROGRAM changes the format of the TD GRID Program and generates a plot of TD's at intervals of 5' of latitude and longitude. This warped lattice, consisting of a computer listing and tape, for the chart under consideration, is sent to NOS for chart latticing.

Originally, the WARPED LATTICE PROGRAM was designed to incorporate theoretical ASF computed by Millington's Method. It has been reformatted to improve lattice accuracy by taking advantage of empirical ASF data collected from USCG and NOS surveys, which began in 1977. Figure 3 depicts the warped lattice.

ACCURATE RAPID ADDITIONAL SECONDARY PHASE FACTOR CORRECTION (ARAD) is a software system developed by Webster Research Corporation of Silver Spring, Maryland for use in the ASF Project. Figure 4 is a data flow chart.

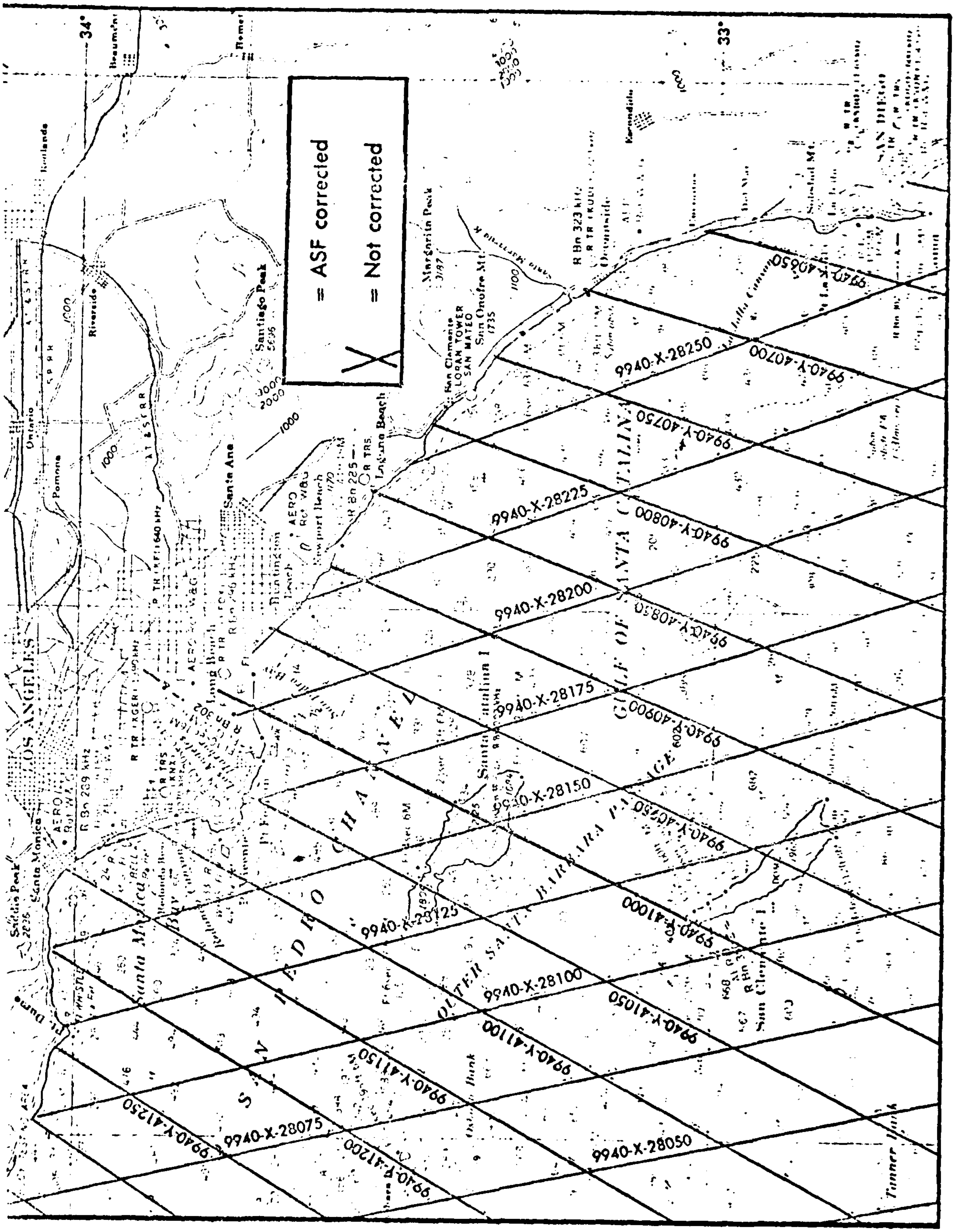


Fig. ~~6~~ Warped Lattice Chart

ARAD System Data Flow

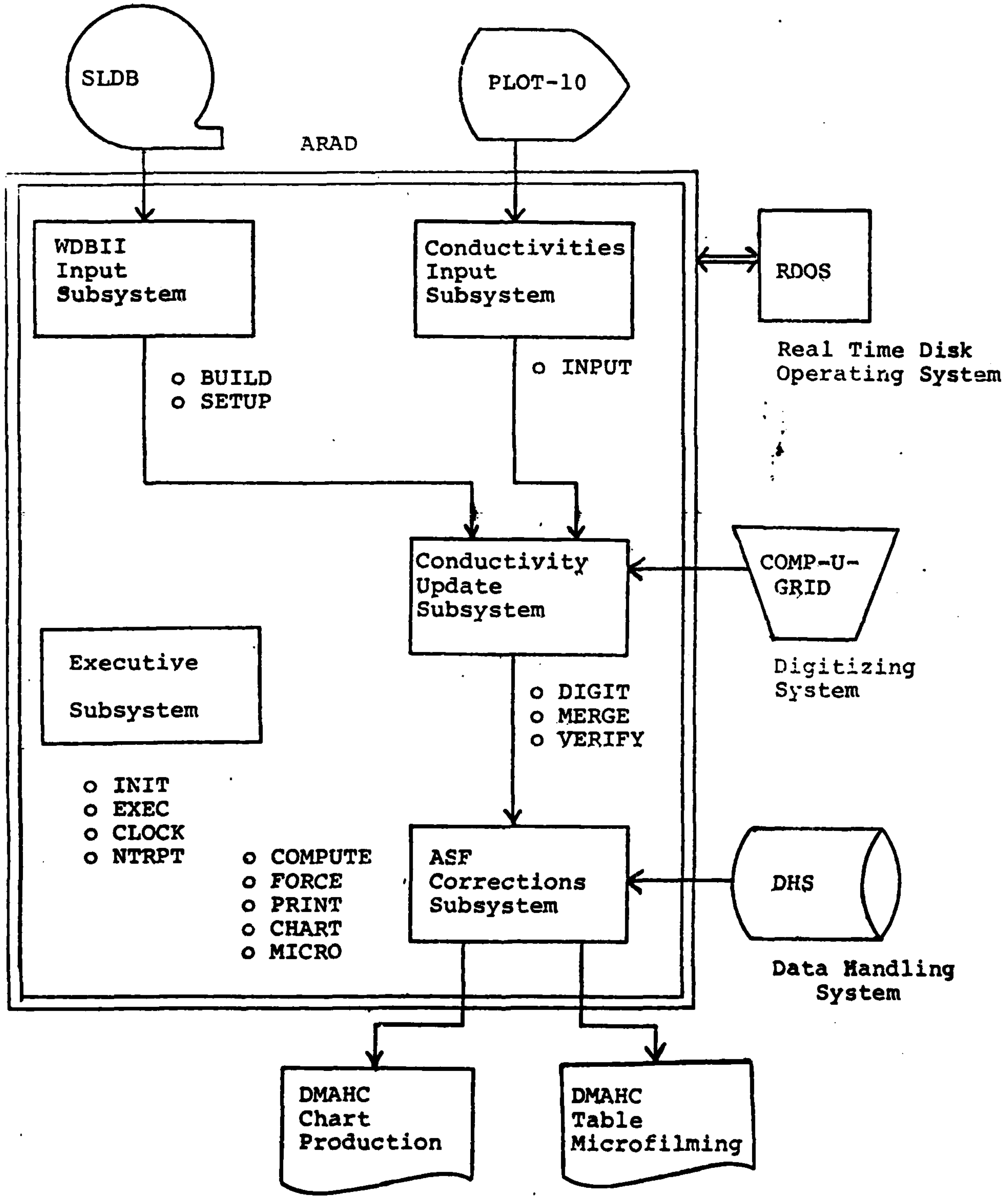


Fig. 4

$$\underline{\hat{x}} = MH^T(HMH^T)^{-1}\,\underline{z}$$

where

$\underline{\hat{x}}$ is the optimal estimate of residual Loran-C errors

M is the error covariance matrix

H is the measurement matrix

$\underline{z}$ is the measurement vector (known residual error)

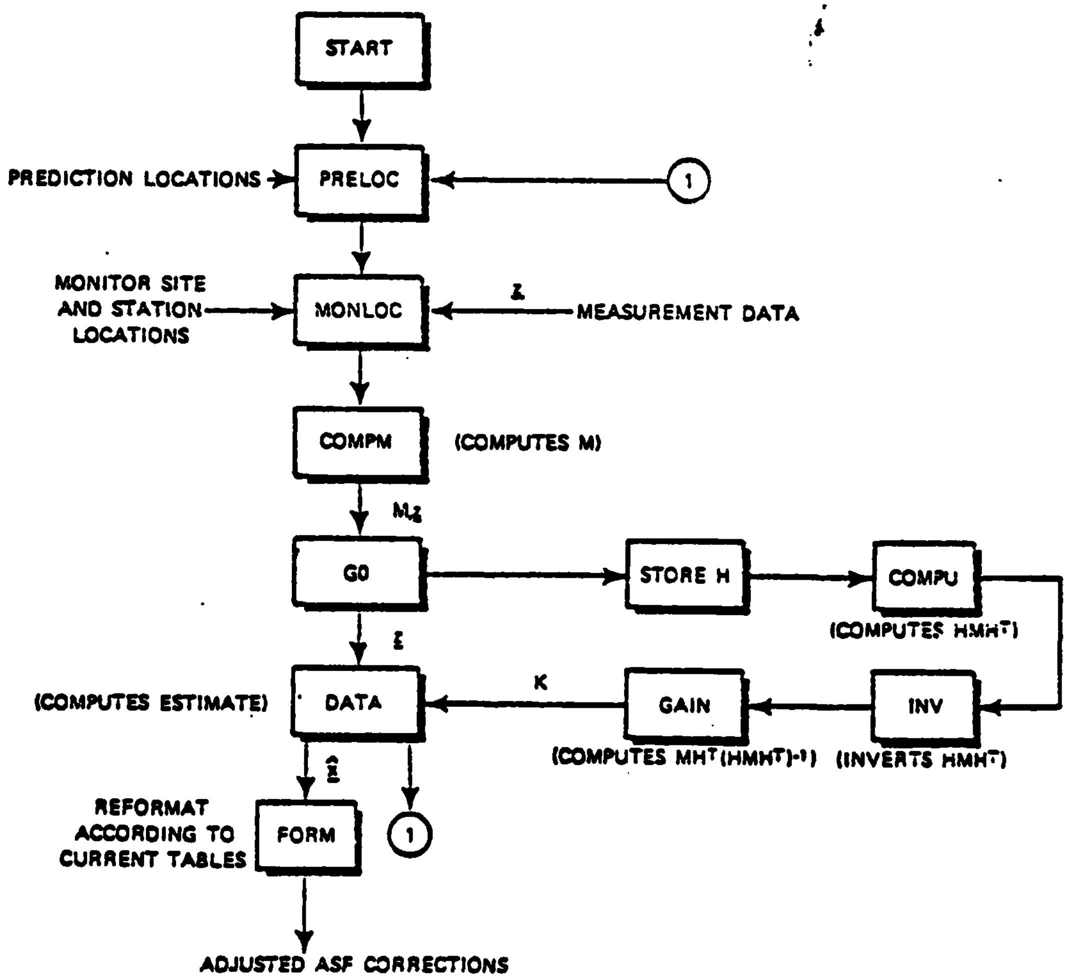


Fig. 5 Flow Diagram for Force-Fit Implementation

ARAD merges the Coast Guard terrain conductivities, the hydrographic shoreline data base (SLDB) map,the Analytic Sciences Corporation (TASC), Loran-C force-fit and DMAHTC ASF determination software programs. The end product is a software system that will enable the Electronic Navigation Division to determine an ASF correction for any geographic position - worldwide.

In the TASC force-fit portion of the overall ARAD effort falls the requirement for empirical or observational data. By utilizing these data DMAHTC updates the data base that is used to produce ASF corrections. The fundamental concept of the force-fit algorithm is based on the postulation of a mathematical relationship between residual errors at known locations (monitor stations and sites) and at locations where no error information is available. This algorithm forces a fit of residual errors in a local area where data are available and then imposes this fit in neighboring areas via a distance-weighting scheme. The adjustments computed via the force-fit algorithm are added to the conductivity-derived corrections; thus the current ASF models and algorithms are not necessarily altered. Presently, the force-fit technique is being implemented using the batch processing method whereby all measurements are processed at a single time. The mathematical form and flow diagram for force-fit implementation is shown in Figure 5.

In 1977, test cases were run using data from three Loran-C chains: East Coast (9930), Southeast Asia (SEA), and Northwest Pacific (9970). Values of percentage improvement for the three chains are shown in Table 1.

TABLE I

LORAN-C ACCURACY IMPROVEMENT USING FORCE-FIT TECHNIQUES

Chain	% Improvement
U.S. East Coast	27
SEA	71
Northwest Pacific	15

Differences in the results may vary with several factors that are a function of the calibration procedure, location of chain, time period of calibration, etc.

LORAN-C CORRECTION TABLES

TABLE DESCRIPTIONS

Each table contains a complete chain. A table section is prepared for each station pair (master station and one secondary station) in a Loran-C chain. As a rule the limits of the table coverage are determined by the range of the groundwave transmissions for the Loran-C chain. Each page of corrections in the table covers an area 3^{o} in latitude by 1^{o} of longitude, with corrections printed in increments of 5' of arc. The latitude values are printed in the left-hand column of each correction page. The longitude values are printed in the upper and lower row of the page. Rate designation and page numbers are printed at the top of each correction page.

Pages are numbered from left to right, starting in the upper left corner of the area, as shown in page index with each section of the tables. Those pages on which the latitude and longitude limits include all land will be omitted and their numbers transferred to the next appropriate page. Those pages where latitude and longitude limits contain both land and sea are included but contain corrections only for the area covered by the U.S. Coastal Conference Zone. Large land bodies and areas outside the CCZ will be represented by blank spaces on the page.

ASF correction values can be either positive or negative. Negative values are indicated by a negative sign preceding the number. The positive values are shown without sign. Areas requiring no correction show a zero value which in some cases is preceded by a negative sign. The negative sign preceding a zero results from the rounding off of a value slightly less than zero and indicates the trend of the correction.

USE OF TABLES

The ASF Correction Tables are published primarily for precision navigation, utilizing digital computers to convert Loran-C time differences to geographic coordinates. This does not preclude use of the tables with manual plotting methods.

Although the ASF Corrections are generally too small to affect a Loran-C fix plotted on a small scale chart, they can become as large as ± 4 microseconds. This offset in feet will be minimal on the baseline, but in other areas of coverage this offset is appreciable due to expansion of lane width between hyperbolas. For example, at $32^{\circ}00'$N. and $80^{\circ}00'$W, using lattice pair 9960-x, a 4 microsecond error will offset the 9960-X line of position by approximately 8000 feet.

The table can be entered directly by using the ship's position determined to the nearest 5' of arc in latitude and longitude either by dead reckoning or some other means. To find the page with the appropriate correction, the Page Indexes of the table must be utilized. These indexes show the limits and page number of all pages in the table. Enter the index with the ship's position and locate the number of the page on which the desired correction is found. In some cases the ship's position will fall on the page limit in either latitude or longitude or both. These positions are repeated on both pages and either page may be used. The ASF Correction is added algebraically to the time difference for the Loran-C pair. Many users having electronic computers will enter these values directly into the computer. While in the area where the corrections apply, the values will be applied automatically to all sampled time differences for particular pairs. The geographic position determined from the corrected time differences will provide a more precise position.

TABLE LIMITATIONS

Interpolation of these data will not necessarily improve accuracy since the information is not of a linear nature. The correction nearest the derived latitude and longitude should be applied to the appropriate time difference.

ASF Corrections should be used with caution for areas within 10 nautical miles of land. This area represents an unreliable zone where large variations occur in the magnitude of the correction.

CAUTION

This table is not to be used with a chart that provides a corrected lattice. Charts which portray corrected lattices contain one of the following notes:

> "The Loran-C lines of position overprinted on this chart have been prepared for use with groundwave signals and are presently compensated only for theoretical propagation delays, which have not yet been verified by observed data. Mariners are cautioned not to rely entirely on the lattices in inshore waters. Skywave corrections are not provided."

or

> "The Loran-C lines of position overprinted on this chart have been prepared for use with groundwave signals and are compensated with propagation delays computed from observed data. Mariners are cautioned not to rely entirely on the lattices in inshore waters. Skywave corrections are not provided."

EXAMPLE

Loran-C receiver dial readings sampled by the computer are 12153.31 microseconds and 44451.83 microseconds for pairs 9960-W and 9960-Y respectively. From these readings the computer determines a position of $44^{\circ}15.1'$N. latitude and $67^{\circ}25.4'$W. longitude. Entering the page Index of Section W with the latitude and longitude nearest to the computed ship's position, the page number containing the derived geographics is found to be 17 W, example page. Entering page 17 W the correction at $44^{\circ}15'$N and $67^{\circ}25'$W is 1.5 microseconds. On page 17 Y, example page, at the same position the correction is 2.7 microseconds.

DATE 1114[illegible]

9960-W 17W

LONGITUDE WEST

LATITUDE NORTH		68 0	55	50	45	40	35	30	25	20	15	10	5	67 0
45	0													
	55													
	50													
	45													2.0
	40												1.7	1.6
	35									1.7	1.7	1.6	1.6	1.6
	30							1.7	1.6	1.6	1.6	1.5	1.5	1.5
	25					1.6	1.5	1.5	1.6	1.6	1.6	1.5	1.5	1.5
	20	1.6	1.5	1.6	1.6	1.5	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	15	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4
	10	1.5	1.4	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3
	5	1.4	1.4	1.5	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	
44	0	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.3	1.3			
	55	1.3	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.2				
	50	1.3	1.3	1.3	1.3	1.3	1.3	1.3						
	45	1.3	1.3	1.2	1.3	1.3	1.3							
	40	1.2	1.2	1.3	1.3	1.3								
	35	1.3	1.2	1.3										
	30	1.3	1.3	1.3										
	25	1.2	1.3	1.3										
	20	1.2	1.3	1.3	1.3									
	15	1.2	1.3	1.3	1.3	1.3								
	10	1.2	1.2	1.3	1.3	1.3								
	5	1.2	1.2	1.2	1.3	1.3	1.3							
43	0	1.2	1.2	1.2	1.2	1.3	1.3	1.3						
	55	1.2	1.2	1.2	1.2	1.3	1.3	1.3						
	50	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3					
	45	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3				
	40	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3			
	35	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3			
	30	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3			
	25	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.2	1.3	1.3	1.3	1.3
	20	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.2	1.2	1.2	1.2	1.3
	15	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.2
	10	1.2	1.1	1.2	1.2	1.2	1.2	1.2	1.3	1.2	1.2	1.2	1.3	1.2
	5	1.2	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
42	0	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
		68 0	55	50	45	40	35	30	25	20	15	10	5	67 0

LONGITUDE WEST

FIG 6

9960-Y 17Y

LONGITUDE WEST

		68 0	55	50	45	40	35	30	25	20	15	10	5	67 0
45	0													
	55													
	50													
	45													7.4
	40												3.1	3.[illegible]
	35									3.0	3.1	3.0	2.9	2.9
	30							2.9	2.9	2.9	2.9	2.8	2.8	2.8
	25					2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.7	2.7
	20	2.9	2.7	2.7	2.7	2.7	2.7	2.7	2.8	2.7	2.7	2.6	2.7	2.6
	15	2.7	2.6	2.6	2.7	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.4
	10	2.7	2.6	2.6	2.7	2.7	2.6	2.6	2.5	2.5	2.6	2.6	2.6	2.6
	5	2.5	2.6	2.6	2.6	2.5	2.5	2.4	2.4	2.4	2.5	2.5	2.5	
44	0	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.3	2.4	2.4			
	55	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4				
	50	2.4	2.4	2.4	2.4	2.4	2.4	2.4						
	45	2.4	2.4	2.3	2.4	2.4	2.4							
	40	2.3	2.3	2.3	2.4	2.4								
	35	2.4	2.4	2.4										
	30	2.4	2.4	2.4										
	25	2.4	2.4	2.4										
	20	2.4	2.4	2.4	2.4									
	15	2.4	2.4	2.4	2.4	2.4								
	10	2.4	2.4	2.4	2.4	2.4								
	5	2.4	2.4	2.4	2.4	2.4	2.4							
43	0	2.4	2.4	2.4	2.4	2.4	2.4	2.4						
	55	2.4	2.4	2.4	2.4	2.4	2.4	2.4						
	50	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4					
	45	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4				
	40	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4			
	35	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4			
	30	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4			
	25	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.5
	20	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	15	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	10	2.4	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	5	2.4	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
42	0	2.4	2.3	2.3	2.4	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
		68 0	55	50	45	40	35	30	25	20	15	10	5	67 0

LONGITUDE WEST

Fig 7

The ASF corrections are applied to the dial readings as follows:

WTD	12153.31	YTD	44451.83
ASF CORRECTION	1.5	ASF CORRECTION	2.7
CORRECTED TO	12154.81	CORRECTED TO	44454.53

The corrected dial readings are used to recompute a new latitude and longitude for the Loran-C fix. The new position is $44^{o}15.4'$N. latitude and $67^{o}26.4'$W. Figures 6 and 7 are example pages.

NATIONAL OCEAN SURVEY (NOS) WEST COAST SURVEY

In 1977, to verify predicted lattices derived from the Warped Lattice and ARAD Programs, the USCG and NOS began surveys in critical areas of the CCZ. The following surveys have been completed:

Chain	Rate
Northeast	9960
Southeast	7980
Great Lakes	8970,9960
West Coast	9940
Straits of Juan de Fuca	9940

The West Coast Survey, which represents the procedures used, is discussed here:

> In the summer of 1977, during field tests of the Loran-C chain 9940, the U.S. Coast Guard discovered apparent differences between predicted and observed Loran-C values in the offshore area between Point Arguello and San Diego. The errors, in the south-southwest direction, appeared to be 1 mile in the Santa Barbara area; 1½ miles in the Los Angeles area; and 2 miles in the San Diego area. The charts involved were: 18720, 18740, 18721, 18746, 18765. Figure 8 shows the area and charts.

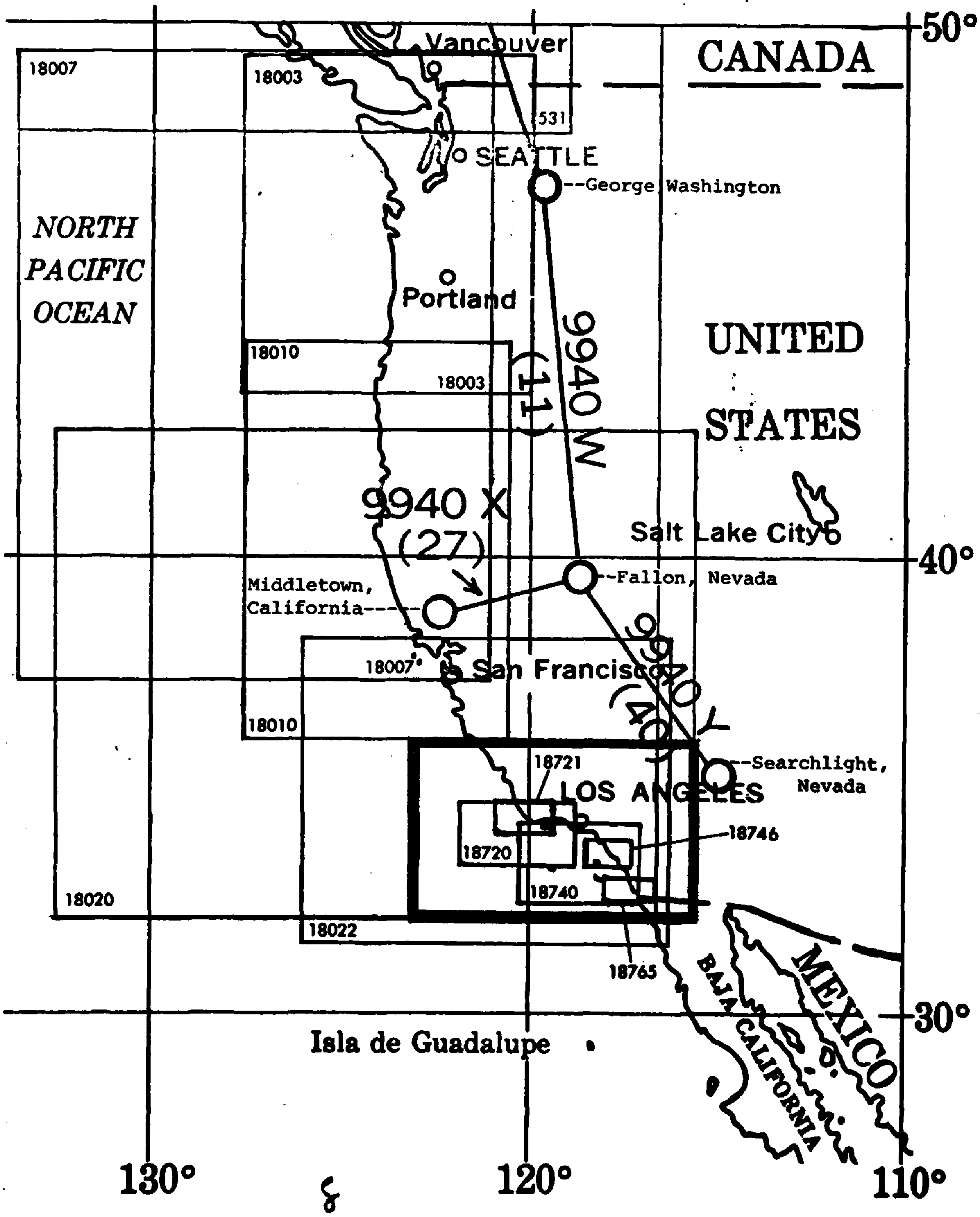


Fig. 8 Empirical Study Chart Coverage

NOAA SHIP RAINIER
ADVANCE INFORMATION
SUBJECT TO OFFICE REVIEW

SP-PMC-6-RA-77
LORAN-C COMPARISON
SOUTHERN CALIFORNIA
SEPT. 25 - OCT. 6, 1977
NOAA SHIP RAINIER
JAMES P. RANDALL, CAPT., NOAA
COMMANDING

J.D.		TIME		LORAN-C RATES RECEIVER 1		RECEIVER 2		RAYDIST/MINI-RANGER POSITION LATITUDE N	LONGITUDE W
268		215100	1	277925	419354	277923	419353	34 44 04.2	120 49 55.7
		215400		277926	419351	277926	419349	34 44 02.4	120 49 53.8
		215700		277927	419352	277925	419352	34 44 03.4	120 49 53.7
		220000		277926	419354	277926	419353	34 44 05.9	120 49 53.5
		220300	5	277942	419343	277939	419340	34 44 10.1	120 49 24.5
		220600		277964	419317	277965	419315	34 44 14.7	120 48 37.9
		220900		277981	419288	277978	419288	34 44 01.7	120 48 07.0
		221200		277997	419266	277997	419265	34 43 56.8	120 47 34.0
		221500		278003	419234	278002	419232	34 43 27.1	120 47 20.7
	10	221800	10	278011	419200	278010	419198	34 42 57.5	120 47 05.1
		222100		278018	419168	278017	419166	34 42 28.1	120 46 51.2
		222400		278025	419137	278024	419136	34 41 59.2	120 46 37.6
		222700		278032	419103	278032	419102	34 41 30.0	120 46 23.8
		223000		278038	419072	278038	419071	34 41 00.9	120 46 10.1
		223300	15	278045	419040	278043	419039	34 40 31.6	120 45 56.5
		223600		278052	419009	278051	419007	34 40 02.1	120 45 42.7
		223900		278060	418974	278058	418974	34 39 32.8	120 45 27.9
		224200		278068	418943	278065	418942	34 39 03.7	120 45 13.9
		224500		278073	418911	278073	418910	34 38 34.9	120 45 00.5
	20	224800	20	278079	418879	278079	418877	34 38 06.3	120 44 46.6
		225100		278087	418846	278085	418846	34 37 37.7	120 44 32.7
		225400		278093	418816	278092	418814	34 37 08.5	120 44 18.6
		225700		278100	418784	278099	418782	34 36 38.7	120 44 04.8
		230000		278106	418750	278106	418748	34 36 08.5	120 43 51.5
		230300	25	278114	418717	278110	418717	34 35 38.0	120 43 36.6
		230600		278119	418685	278118	418684	34 35 08.2	120 43 22.8
		230900		278126	418653	278124	418652	34 34 38.7	120 43 09.2
	28	231200		278133	418621	278132	418621	34 34 09.8	120 42 55.1
	31	233000		270207	418540	270206	418539	34 34 17.1	120 40 30.4
		233300	30	278196	418577	278195	418575	34 34 45.5	120 40 51.5
		233600		278189	418612	278188	418610	34 35 17.1	120 41 06.3
		233900		278184	418645	278182	418644	34 35 48.8	120 41 20.6
		234200		278177	418678	278176	418670	34 36 20.9	120 41 34.4

Fig. 9 Computer Printout

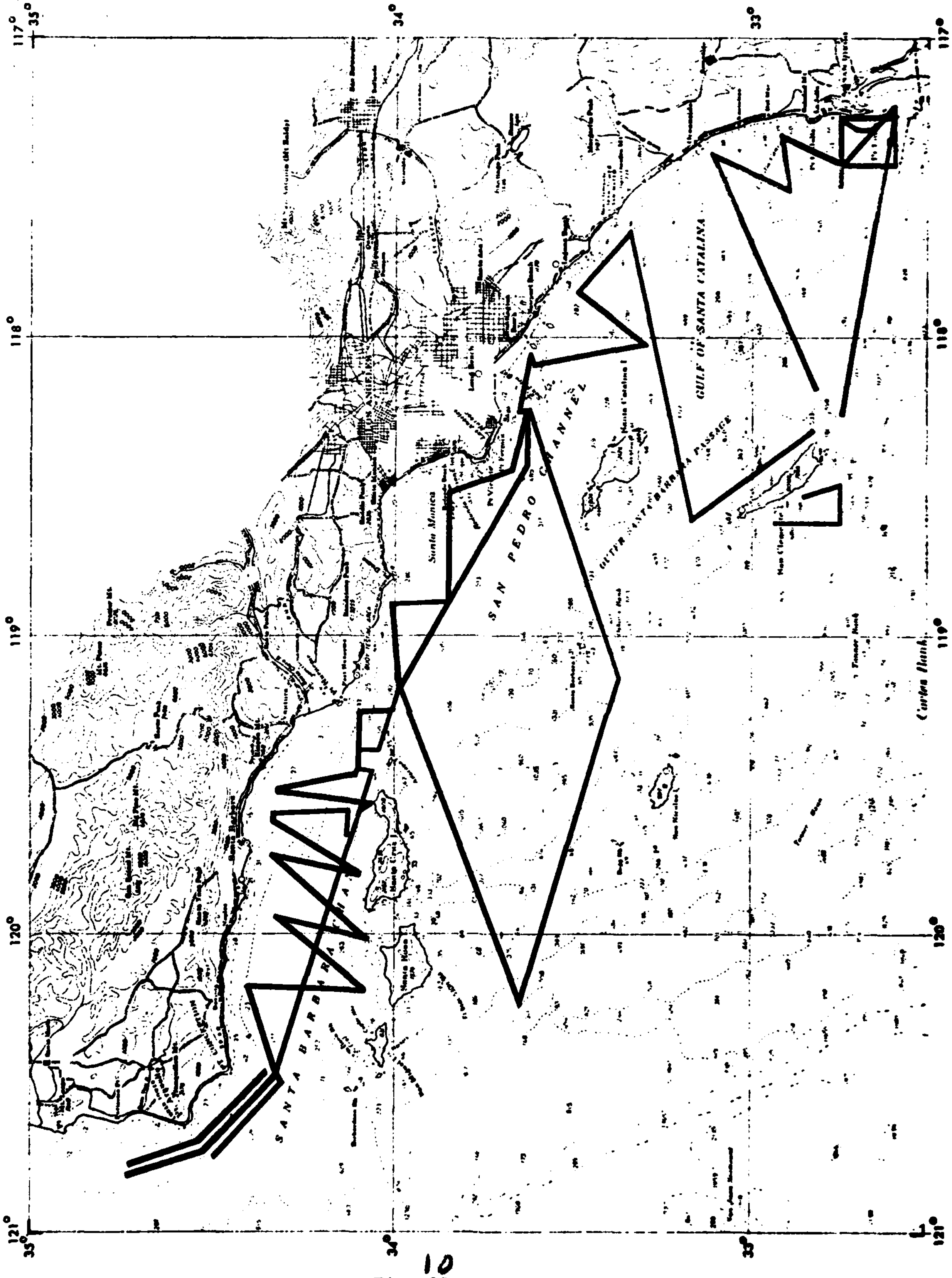


Fig. 10 [redacted] Track Chart

Because of the heavy volume of vessel traffic in this area, the Coast Guard through NOS, requested the NOAA Ship Rainier to run a series of tracks taking simultaneous Raydist/Mini-Ranger geographical positions (GP) and Loran-C time differences (TD), using Loran-C pairs 9940-X and 9940-Y. In addition, upon completion of the survey the Coast Guard requested that the Rainier forward the collected data to the Electronic Navigation Division, DMAHTC, for analysis and evaluation. The formats were a computer printout of the Raydist/Mini-Ranger GP's and Loran-C receiver TD's (figure 9) and a track chart with numbered fix points corresponding to each reading on the computer printout. There were 1600 fix points. Figure 10 is a small scale version of the track chart. In the area covered by the above listed charts the USCG's primary concern was to insure traffic separation in the shipping lanes. The survey data proved to be more accurate than the theoretical predictions. Consequently, these data were used to provide ¼ NM accuracy.

CONCLUSION

As mentioned previously, the Warped Lattice Program and ARAD through the TASC force-fit software program incorporate empirical Loran-C observations to improve predicted Loran-C lattices. Consequently, DMAHTC and the USCG need to collect Loran-C comparisons from as many sources as possible. Figure 11 shows the DMAHTC Calibration Questionnaire, which is included in the weekly Notice to Mariners. Additionally, the USCG and NOS will continue their Loran-C comparison surveys in the CCZ and Great Lakes. For 1981, at least three surveys are planned.

SECTION III

DMAHC LORAN-C CHART CALIBRATION QUESTIONNAIRE

Calibration information is being collected in an effort to evaluate and improve the accuracy of the DMAHC derived LORAN signal propagation corrections incorporated in National Ocean Survey Coastal LORAN-C charts. LORAN-C monitor data consisting of receiver readings with corresponding well defined reference positions are required. Mariners aboard vessels equipped with LORAN-C receiving units and having precise positioning capability independent of the LORAN-C system (i.e., docked locations or visual bearings, radar, navigation satellite, Raydist, etc.) are requested to provide monitor information via the questionnaire found at the back of this Notice to Mariners. Please mail this questionnaire to Defense Mapping Agency Hydrographic Center, Washington D.C. 20390. Attention Code NVE.

DMAHC LORAN-C CHART CALIBRATION QUESTIONNAIRE

VESSEL NAME ______________________________

LORAN-C RECEIVER MAKE AND MODEL ______________________________

OBSERVER ______________________________

GMT	DAY OF YEAR	YR.	LORAN-C TIME DELAY READINGS (XXXXX.XX Usec.) Rate Designations (xxxx)-W	(xxxx)-X	(xxxx)-Y	(xxxx)-Z	REFERENCE POSITION (Ref. Posit. must coincide with time of TD Reading) LATITUDE XX°-XX.X' N/S LONGITUDE XXX°-XX.X' E/W	REFERENCE POSITION SOURCE DESCRIPTION (I.e., Visual Bearings, Radar, Navigation satellite, Raydist, etc. or Pier location, number, & berth desig.)

Fig. [redacted] 11

[redacted]

APPENDIXES

GRAPHICS OF INDIVIDUAL CHAIN COVERAGE IN THE CCZ AND GREAT LAKES

A. CANADIAN EAST COAST CHAIN 5930

B. NORTHEAST U.S. CHAIN 9960

C. GREAT LAKE CHAIN 8970

D. SOUTHEAST U.S. CHAIN 7980

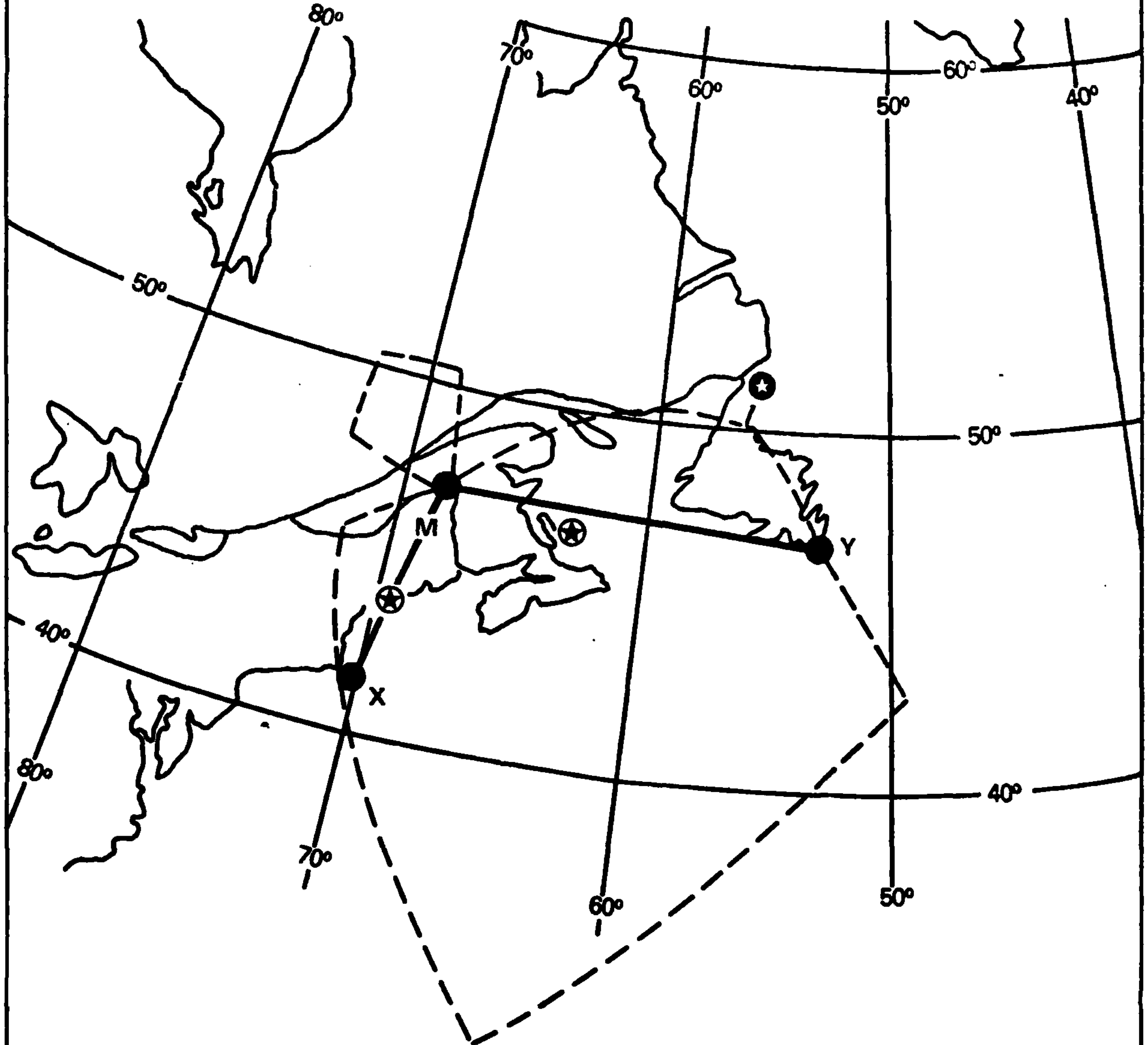
E. WEST COAST CHAIN 9940

F. CANADIAN WEST COAST CHAIN 5990

G. GULF OF ALASKA 7960

LORAN-C

CANADIAN EAST COAST CHAIN
GRI 5930



Approximate Limits of Coverage---1:3 SNR and ¼ NM Fix Accuracy (95% 2dRMS), Noise 50dB

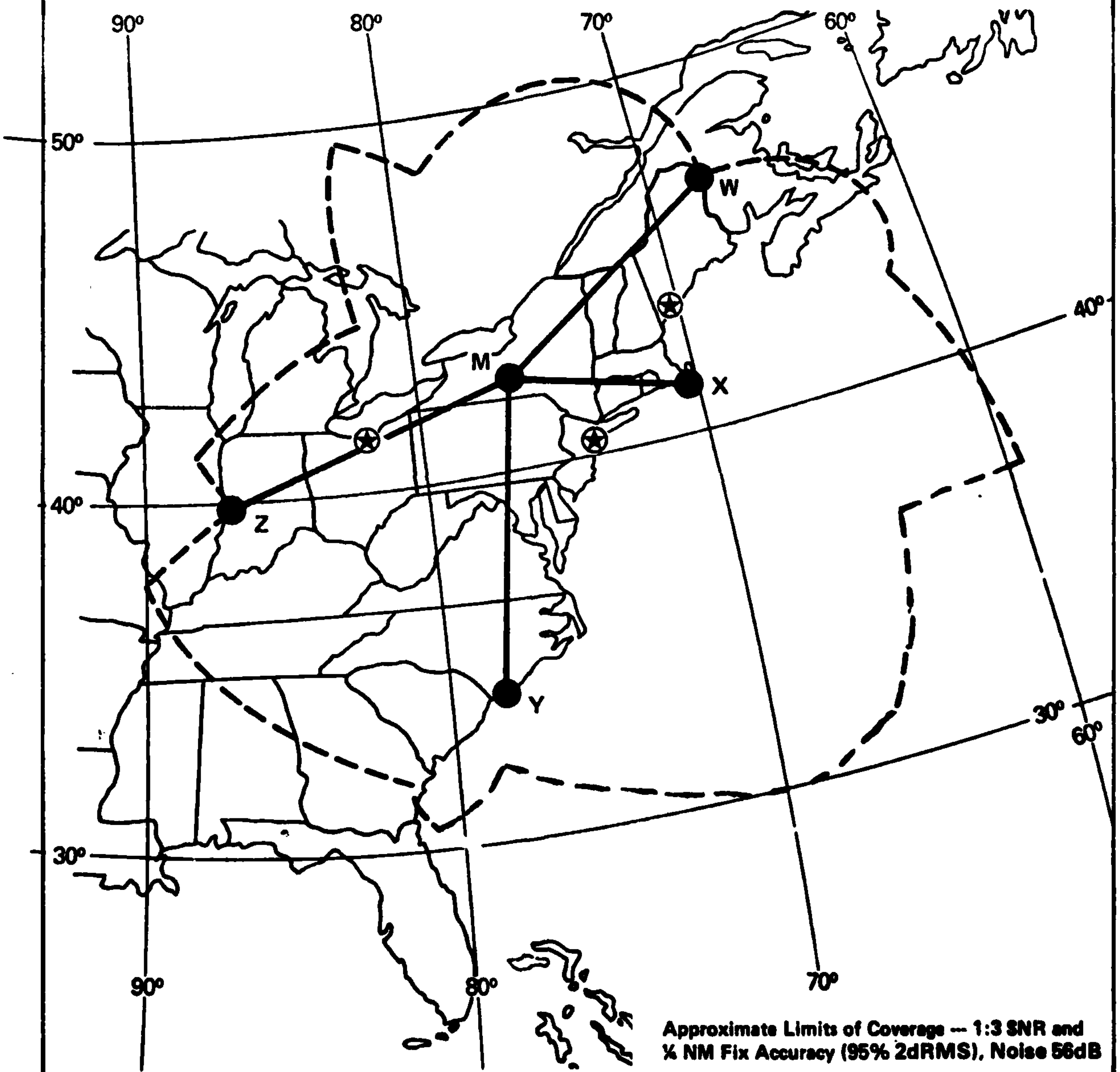
LEGEND:

- ● TRANSMITTING
- MONITOR
- MONITOR (AUTOMATED)

M CARIBOU
X NANTUCKET
Y CAPE RACE

LORAN-C

NORTHEAST U.S. CHAIN
GRI 9960

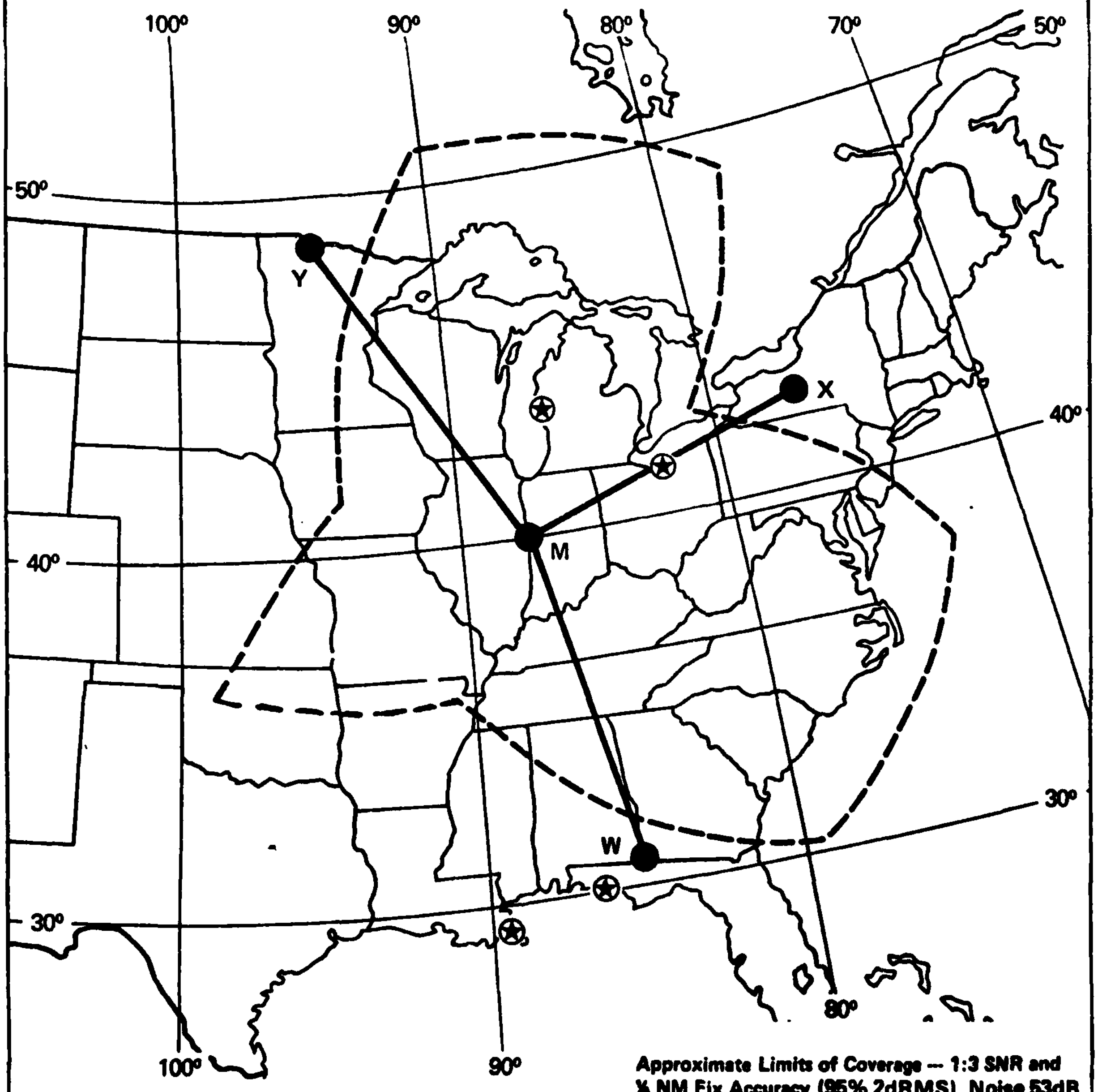


Approximate Limits of Coverage — 1:3 SNR and ¼ NM Fix Accuracy (95% 2dRMS), Noise 56dB

LEGEND:
- TRANSMITTING
- MONITOR
- MONITOR (AUTOMATED)

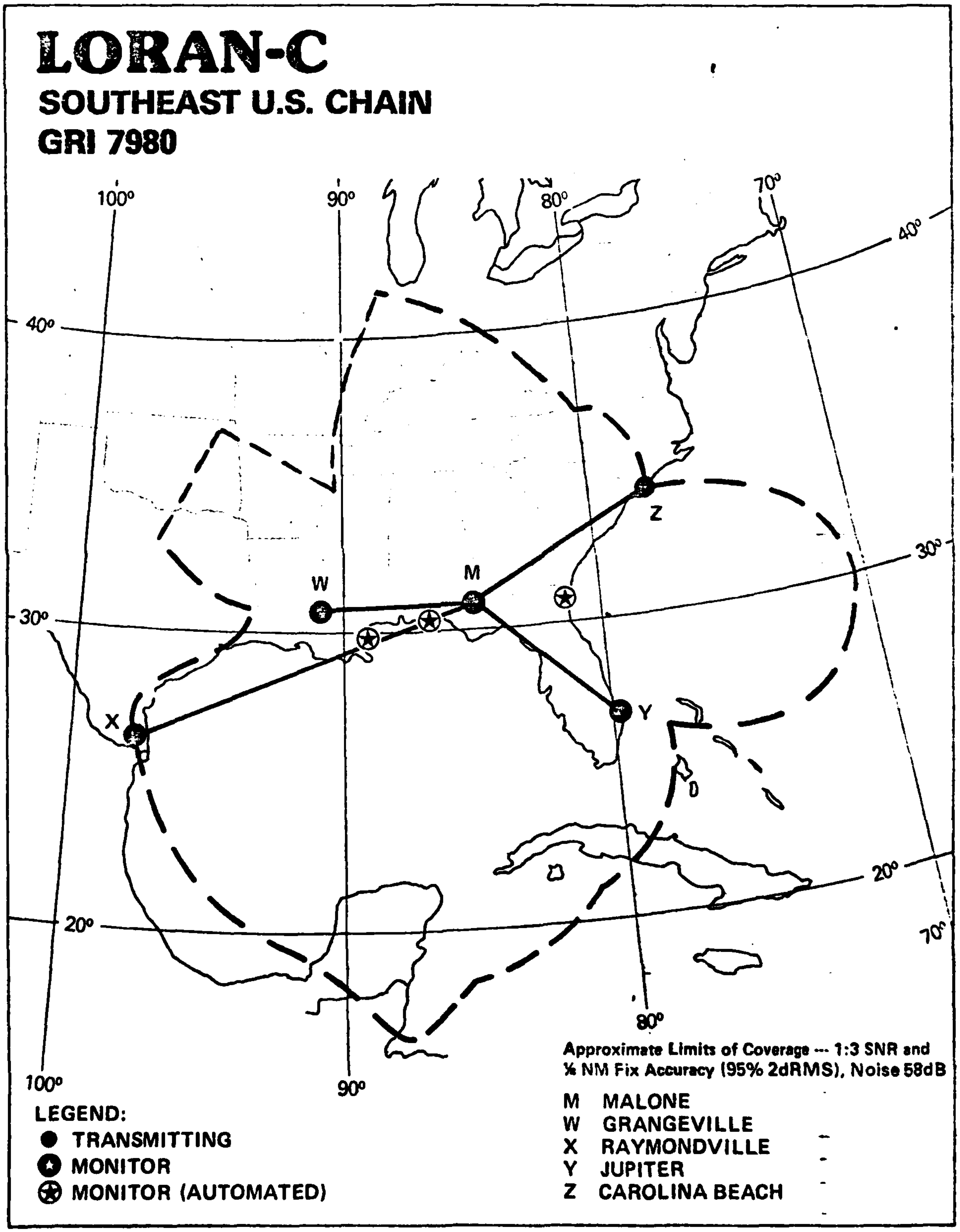
M SENECA
W CARIBOU
X NANTUCKET
Y CAROLINA BEACH
Z DANA

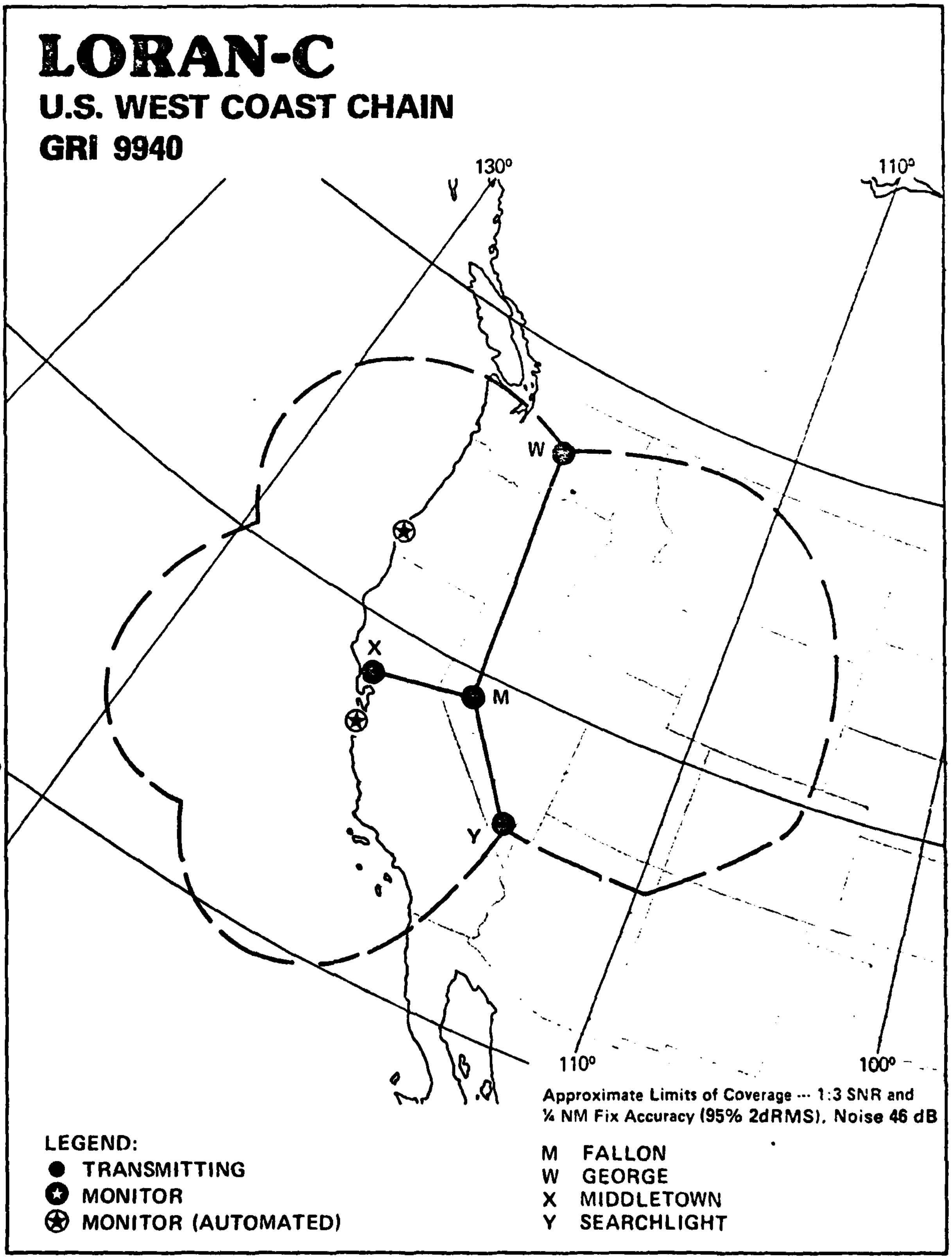
LORAN-C
GREAT LAKES CHAIN
GRI 8970

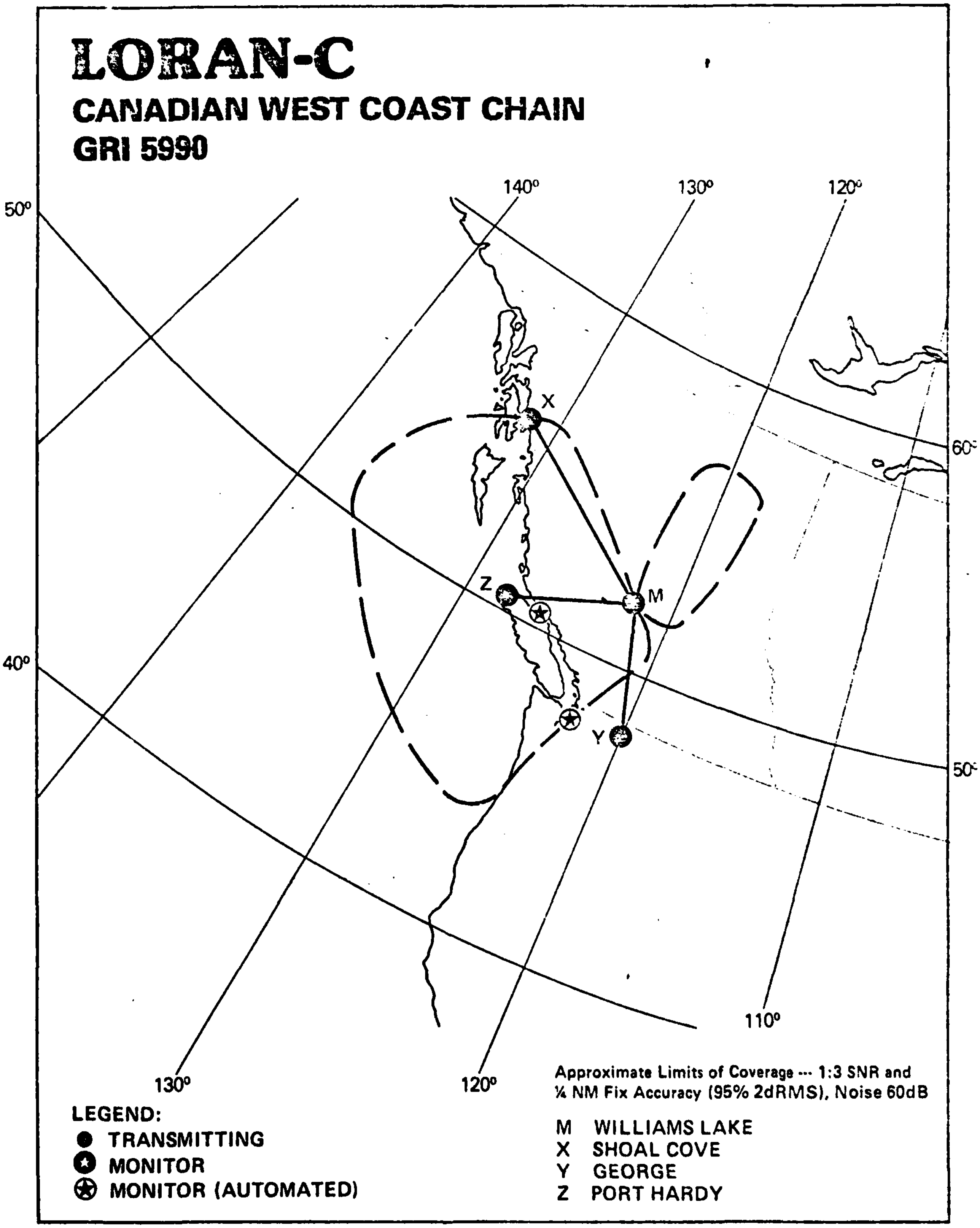


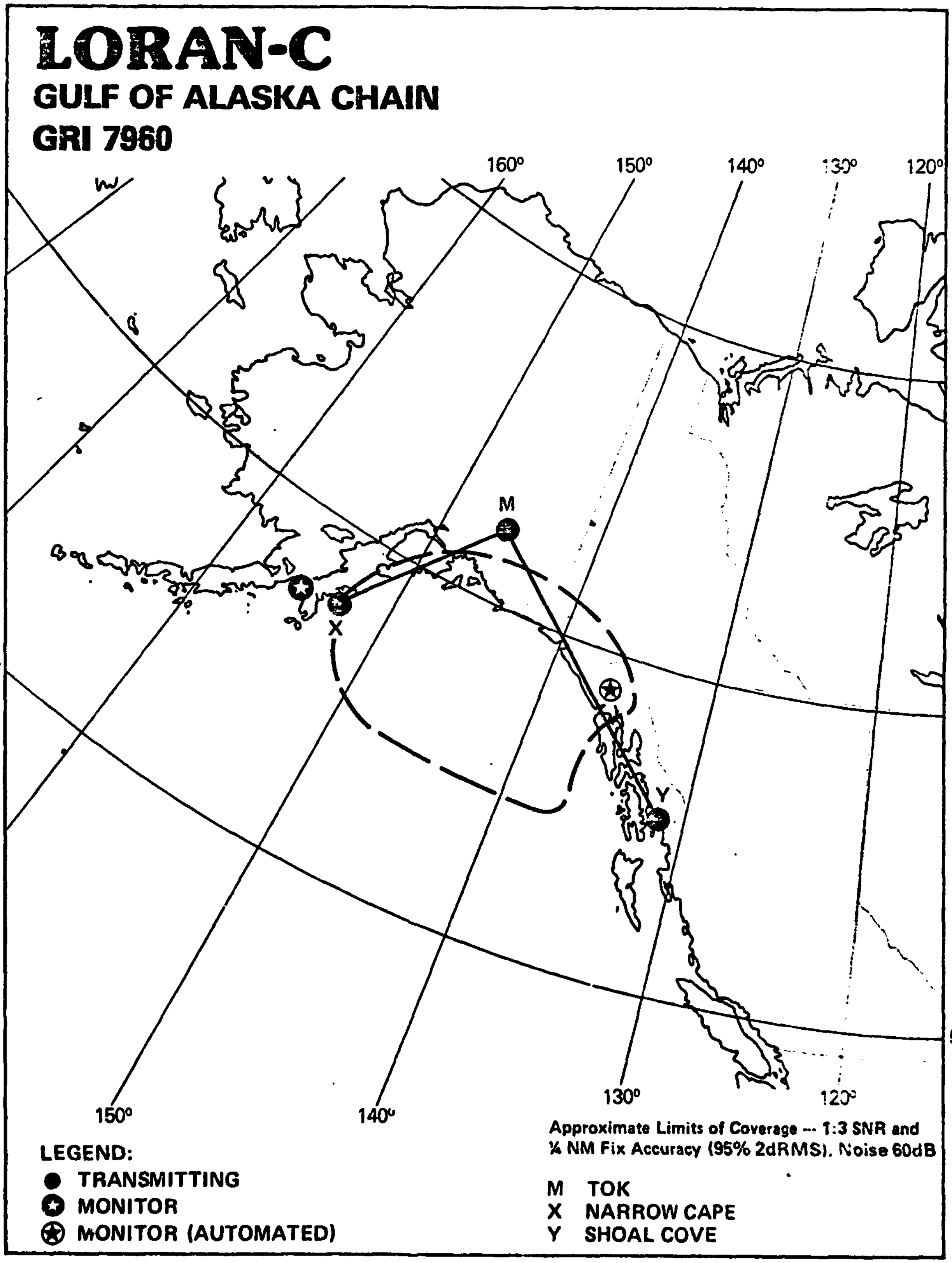
LEGEND:
- TRANSMITTING
- MONITOR
- MONITOR (AUTOMATED)

M DANA
W MALONE
X SENECA
Y BAUDETTE


LORAN-C
SOUTHEAST U.S. CHAIN
GRI 7980
100°
90°
80°
70°
40°
30°
20°
W
M
Z
X
Y
Approximate Limits of Coverage --- 1:3 SNR and ¼ NM Fix Accuracy (95% 2dRMS), Noise 58dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M MALONE
W GRANGEVILLE
X RAYMONDVILLE
Y JUPITER
Z CAROLINA BEACH


LORAN-C
U.S. WEST COAST CHAIN
GRI 9940
130°
110°
40°
50°
30°
40°
110°
100°
W
X
M
Y
Approximate Limits of Coverage --- 1:3 SNR and
¼ NM Fix Accuracy (95% 2dRMS). Noise 46 dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M FALLON
W GEORGE
X MIDDLETOWN
Y SEARCHLIGHT


LORAN-C
CANADIAN WEST COAST CHAIN
GRI 5990
140°
130°
120°
50°
60°
40°
50°
110°
130°
120°
X
Z
M
Y
Approximate Limits of Coverage --- 1:3 SNR and
¼ NM Fix Accuracy (95% 2dRMS), Noise 60dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M WILLIAMS LAKE
X SHOAL COVE
Y GEORGE
Z PORT HARDY


LORAN-C
GULF OF ALASKA CHAIN
GRI 7960
160°
150°
140°
130°
120°
60°
70°
50°
60°
50°
M
X
Y
150°
140°
130°
120°
Approximate Limits of Coverage -- 1:3 SNR and ¼ NM Fix Accuracy (95% 2dRMS). Noise 60dB
LEGEND:
TRANSMITTING
MONITOR
MONITOR (AUTOMATED)
M TOK
X NARROW CAPE
Y SHOAL COVE

DATE
FILMED

8